USDA photo-illustration by Stephen Thompson

Whey to Ethanol

Is there a biofuel role for dairy cooperatives?

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Editor's note: See page 46 to order the research report that this article is based on.

An estimated 90.5 billion pounds of whey was generated as a byproduct of U.S. cheese production in 2006. Besides the liquid carrier, the composition of whey is approximately 0.3 percent butterfat, 0.8 percent whey proteins, 4.9 percent lactose, and 0.5 percent minerals. So there was 4.4 billion pounds of lactose contained in the whey produced that year.

Whey may be made into many products with various processes and technologies. Condensed whey, dry whey, dry modified whey, whey protein concentrate and isolates, as well as lactose (crystallized and dried), are all whey products. There are many other secondary and tertiary products that can be derived from whey, but the volume of whey used in these products is relatively small.

Whey products produced in 2006 were estimated to contain 1.9 billion pounds of lactose. That means there was about 2.5 billion pounds of surplus lactose not used for whey products. This vast amount of surplus lactose could be fermented to produce an estimated 203 million gallons of ethanol. This assumes complete consumption of lactose in fermentation and ethanol conversion efficiency at 100 percent of the theoretical yield.

Dairy cooperatives' share of the whey-ethanol potential could be 65 million gallons. There are two industrial-scale whey-ethanol plants in the United States, at Corona, Calif. (although this plant is slated for closure), and Melrose, Minn. Both began operation in the 1980s and are currently owned and operated by dairy cooperatives. Together, they produce 8 million gallons of fuel ethanol a year.

The whey-to-ethanol plant commissioned in 1978 by Carbery Milk Products Ltd. of Ireland is believed to be the first modern commercial operation to produce potable (drinkable) alcohol. Starting in 1985, it has produced fuel ethanol as well. The Carbery process developed by the company has been adopted by plants in New Zealand and the United States. New Zealand started using fuel ethanol produced from whey in August 2007.

Conversion process

All ethanol production processes share some basic principles and steps. Whey permeate from protein ultra-filtration is concentrated by reverse osmosis to attain high lactose content. Lactose is fermented with some special strains of yeast. Once the fermentation has been completed, the liquid (beer) is separated and moved to the distillation process to extract ethanol.

This ethanol is then sent through the rectifier for dehydration and then denatured. The effluent (stillage and spent yeast) may be discharged to a treatment system, digested for methane gas, then sold as feed or further processed into food, feed or other products.

To be economically viable, a dehydration plant (and by inference, an ethanol plant) needs to have a minimum daily capacity of 60,000 liters of ethanol (about 15,850 gallons a day, or 5 million gallons a year), according to a 2005 New Zealand report. The estimated "at-gate" cost (operating and capital service costs) of producing ethanol from whey permeate at maximum technical potential, with a level of uncertainty of +/- 20 percent, was N.Z. $0.6-$0.7 per liter. Using a currency exchange rate of NZ $1 = U.S. $0.7, the estimated cost translated to U.S. $1.60-1.85 per gallon.

This ethanol plant uses whey from the adjoining cheese plant in Corona, Calif., as its feedstock. However, Dairy Farmers of America (DFA) is closing the cheese plant. Photo courtesy DFA

This estimate is similar to the costs quoted by sources in the United States: about $1 per gallon of operating cost and a capital service cost that is predicated on the capital cost of from $1.50 to $4 per annual gallon for a commercial operation, depending on the scale of the plant. The estimated operating cost assumes that whey permeate used in ethanol fermentation is a free (no cost) feedstock. Capital cost is the cost of the plant construction project.

There is an opportunity cost of lactose for ethanol fermentation only if there are competing uses of the same lactose, such as manufacturing dry whey, lactose or other whey products. If there is no such competition, then the whey permeate somehow has to be disposed of and the opportunity cost of lactose for ethanol fermentation is likely to be zero or even negative.

It would take 12.29 pounds of lactose to produce a gallon of ethanol, if the lactose is completely consumed in fermentation and ethanol conversion efficiency is 100 percent of the theoretical yield. For every $0.01 net lactose value (price of lactose net of processor's cost), the feedstock cost for fermentation would be $0.1229 per gallon of ethanol. If lactose consumption is less than complete in fermentation and ethanol conversion efficiency is less than 100 percent of the theoretical yield, then more than 12.29 pounds of lactose is required to produce a gallon of ethanol and the feedstock cost would be higher.

Economic feasibility

Whether it is economically feasible to produce ethanol from whey permeate is determined by the balance of the production costs and the expected revenues. Net returns from the ethanol enterprise should be measured against the profitability of making other whey products or of other uses, to determine whether ethanol production is a more worthwhile undertaking. A further consideration should be deciding which of the whey enterprises fit better with a cooperative's overall business strategy.

The fact that the two whey-ethanol plants have been in operation for more than 20 years is an indication that: (1) fuel ethanol production from whey is technically feasible, (2) whey-to-fuel ethanol production technologies and processes are mature and capable of being adopted for commercial operations and (3) producing fuel ethanol from whey is economically feasible.

In assessing the feasibility of a new whey-ethanol plant, the cost of whey permeate as feedstock needs to be carefully evaluated in this era of whey products price uncertainties. Other important factors to consider, beside feedstock cost, are: (1) appropriate plant scale that would minimize capital cost and the cost of assembling feedstock, (2) appropriate technology and process that would minimize operating cost, (3) best alternative for using and/or disposing of the effluent, (4) ethanol price and (5) various government production incentives.

Dairy cooperatives are certainly well-positioned to coordinate whey assembly for ethanol production. However, in view of the current high and unsettled dry whey product prices, there are great uncertainties concerning the long-term development of the whey-ethanol production enterprise.

There was a very high attrition rate of fuel ethanol plants during the 1980s. Experiences of that period provide some lessons that may be relevant to future commercial whey-ethanol development. To be successful, a fuel ethanol plant should have proper technology selection, proper engineering design, adequate research support, credible feasibility study, adequate financing and personnel with technical and managerial expertise in the biochemical process. ■